Lake Water Quality Assessment for Bowman-Haley Reservoir Bowman County, North Dakota

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SUMMARY

Bowman-Haley Reservoir is a 1,732-acre impoundment at the confluence of the North Fork of the Grand River, Alkali Creek and Spring Creek. (Figure 1). The dam lies approximately 8 mile east and 14 miles south of the city of Bowman in Bowman County, North Dakota. The dam was built and is maintained and operated by the U.S. Army Corps of Engineers (COE). Construction began in August 1966, and the reservoir was completed and filled by March of 1969. Discharge from the Bowman-Haley Reservoir forms the continuation of the North Fork of the Grand River.

The Bowman-Haley Reservoir was constructed near the end of the COE peak dam-building era. Built primarily for flood control, the structure also provides a reservoir for local water needs and recreation. The bowman-Haley Reservoir dam is impressive at more then a mile across and 79 feet high at the channel. Its bulk is nearly half as large as some smaller COE dams on the mainstem Missouri River.

The North Fork of the Grand River, Alkali Creek and Spring Creek drainages combine to give Bowman-Haley Reservoir a watershed of approximately 475 square miles. The watershed lies in both North and South Dakota within the Missouri Slope Upland physiographic region, a subregion of the Great Plains of the United States. The climate of this region is semiarid to arid. Average annual precipitation ranges from 11 to 16 inches. Between 80 and 90 percent of the annual precipitation comes in April through September, with much of it arriving in brief powerful cloudbursts and thunderstorms. It is an area of extreme cold and heat, drought and flood.

The watershed is comprised primarily of rolling to hilly uplands with small scattered areas of badlands and prominent buttes. Slopes are generally gentle with maximum relief of 300 to 500 feet. The watershed has either never been glaciated or was glaciated so long ago as to have no glacial evidence remaining. Almost the entire watershed is in some type of agriculture use with livestock production predominating.

Bowman-Haley Reservoir is classified by the North Dakota Department of Health (NDDoH) as a warm-water fishery ("waters capable of supporting growth and propagation of nonsalmonoid fishes and associated aquatic biota.") The North Dakota Game and Fish Department (NDGF) manages Bowman-Haley's fishery and the surrounding game management area.

A history of poor water clarity and massive algal blooms prompted the addition of a hypolimnetic drawdown in 1988 and a water quality improvement project in 1990. The COE's hypolimnetic drawdown is designed to allow the discharge of inferior water below the metilimnion during periods of thermal stratification. The system has been relatively unsuccessful as Bowman-Haley Reservoir rarely thermally stratifies.

The water quality improvement project implemented in 1990 was successful at reducing the amount of nutrients and suspended solids reaching Bowman-Haley Reservoir from the Alkali and Spring Creek drainages. The project was funded by a grant through the U.S. EPA Section 319 of the Clean Water Act and several USDA programs. The goal of the project was to reduce agricultural nonpoint source pollution (NPS) discharges to the reservoir through implementation of best management practices (BMPs). The objective is still being accomplished by landowners voluntarily modifying their farming and ranching techniques to protect their soil against water and wind erosion.

The Bowman-Slope Soil Conservation District (SCD) spearheaded the project by applying and receiving the watershed grant in 1990. Since implementing the project in 1990, the SCD has, through one-on-one assistance, influenced the way agricultural producer protect their land on more than half of the 475-square-mile basin. Reduction in NPS discharges to the reservoir has been documented by monitoring nutrient and suspended solids concentrations in Alkali and Spring Creek. For additional information on the project, contact the Bowman-Slope SCD.

A second project that improved the lake during the same time period was a carp population reduction/eradication project. Carp population reduction was part of the NDGF ongoing fisheries management of Bowman-Haley Reservoir. This project, conducted from 1993 through 1995, has removed a significant percentage of the carp population from Bowman-Haley Reservoir and is replacing it with walleye and northern pike. The project began in 1993 with a netting program designed to count and track the movements of carp and other fish species within the reservoir. The second and third years of the project included a repeat of the first-year tracking process and added spot applications of rotenone at opportune times in the bay and inlet areas of the reservoir.

The project was very successful, removing approximately 75 percent of the 1.25 million pounds of undesirable fish biomass in 1994 and 1995. An ancillary benefit from the carp reduction was improved water quality. Water quality benefits included a decrease in shoreline erosion through improved reservoir elevation management, a decrease in bioturbation, an increase in macrophyte density and a 100,000-fold increase in benthic invertebrates in the bay and inlet areas. For additional information on this project, contact the NDGF, Dickinson Field Office, Fisheries Division.

The positive results being realized in Bowman-Haley and surrounding watershed are the product of a small group of dedicated local individuals. The project implementation involved more than 10 public and private organizations (e.g., Bowman-Slope SCD, Natural Resources Conservation Service, Bowman County Water Resource District Board, Bowman-Haley Anglers Association, Ducks Unlimited, the U.S. Fish and Wildlife Service, EPA, NDDoH, NDGF and NDSU Extension).

Access to the Bowman-Haley Reservoir is excellent from state and county roads. Public facilities include areas to camp and picnic, public toilets, two boat ramps and three public use areas.

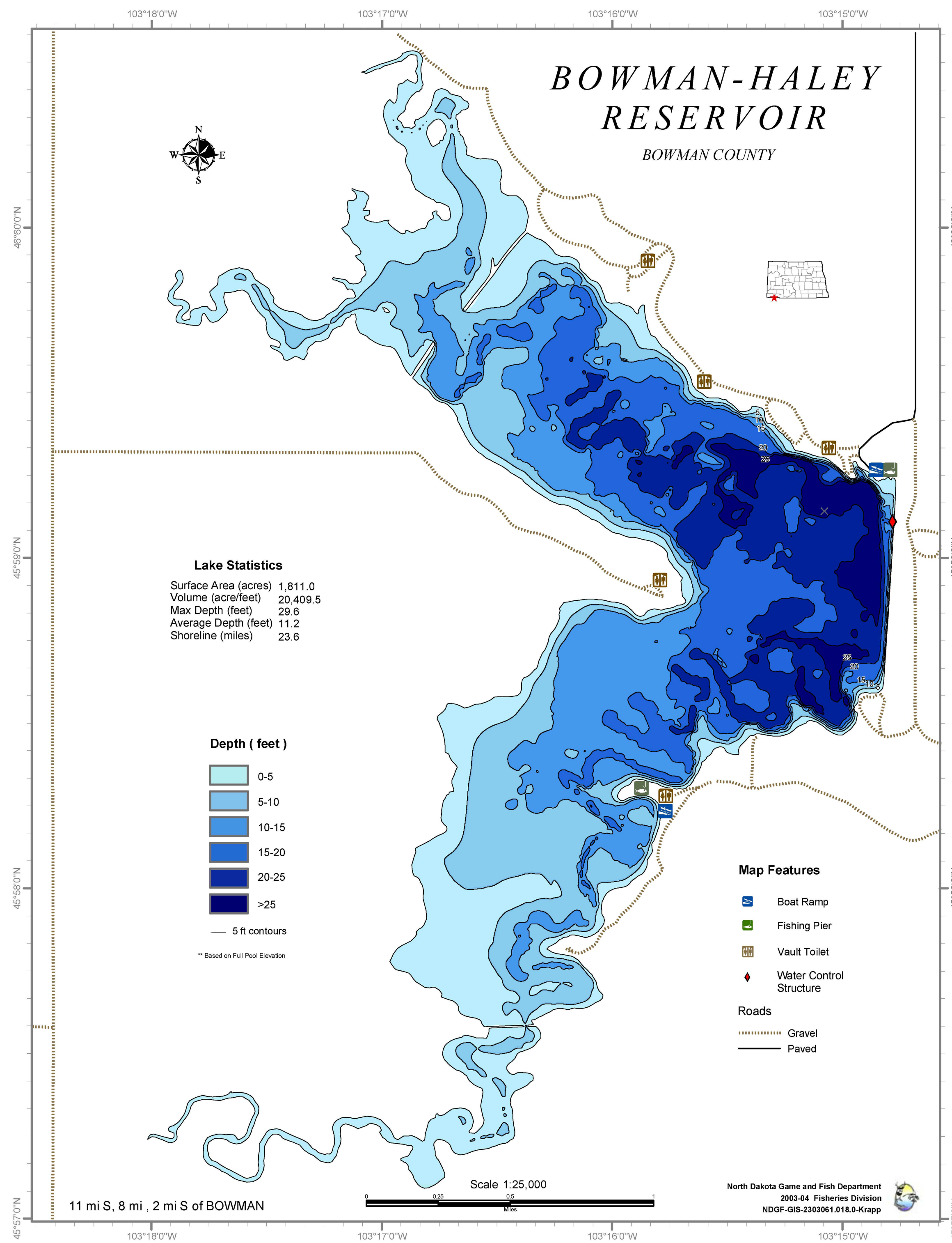

Figure 1. Map of Bowman-Haley Reservoir

WATER QUALITY

Water quality data was collected from three sites on Bowman-Haley Reservoir during the 1994-1995 and 2000-2001 LWQA projects. The primary site was located over the deepest area near the dam, while the second and third sites were located in the south and north arms of the reservoir over the deepest area if no channel could be identified (Figure1).

The chemical and physical data collected during the 1994-1995 and 2000-2001 LWQA projects defined Bowman-Haley reservoir as a eutrophic, well-buffered waterbody that rarely thermally stratifies. Certain dissolved solids concentrations were higher in 2000-2001 than in 1994-1995, but the average nutrient concentrations were similar (though more stable) in 2000-2001 than in 1994-1995. The increase in dissolved solids and the nutrient stability is most likely due to variations in hydraulic discharge.

Alkalinity and bicarbonate concentrations were slightly higher over the deepest area of the reservoir than in the shallower arms. This deeper area also had lower concentrations of nutrients and increased water clarity. These differences are greatest between the south arm and the deepest area (Tables 1, 2 and 3).

Concentrations of total alkalinity as $CaCO_3$ were higher in 2000-2001 than in 1994-1995. In 1994-1995, concentrations of total alkalinity as $CaCO_3$ in the deepest area near the dam ranged from 298 milligrams per liter (mg/L) to 390 mg/L with a volume-weighted mean of 317 mg/L, 308 mg/L in the south arm and 307 mg/L in the north arm. In 2000-2001, concentrations of total alkalinity as $CaCO_3$ in the deepest area near the dam ranged from 350 mg/L to 432 mg/L with a volume-weighted mean of 374 mg/L in the deepest area, 375 mg/L in the south arm and 378 mg/L in the north arm.

Sulfates and bicarbonates were the dominant anions in the water column in both 1994-1995 and 2000-2001. In 2000-2001, sulfate concentration ranges were nearly double the 1994-1995 concentrations, while bicarbonates were only slightly higher. In 1994-1995, sulfate concentrations ranged between 681 mg/L and 781 mg/L, while bicarbonates ranged between 300 mg/L and 476 mg/L. In 2000-2001, sulfate concentrations ranged between 1220 mg/L and 1630 mg/L, while bicarbonates ranged between 348 mg/L and 505 mg/L.

Concentrations of the nutrients total phosphorus as phosphate and nitrate plus nitrite as nitrogen generally ran below the state's long-term average (Table 1, 2 and 3). The total phosphorus as phosphate concentrations ranged between 0.042 mg/L and 0.077 mg/L in 2000-2001 representing an increase over the lowest reading in 1994-1995 of 0.009 mg/L but a decrease in the maximum of 0.103 mg/L.

In 2000-2001, the reported concentrations of total phosphorus as phosphate exceeded the state's water quality standard of 0.02 mg/L in all samples analyzed but stayed under the 1995-2001 long-term average of 0.152 mg/L in all samples collected. For comparison, in 1994-1995, the recorded concentrations of total phosphorus as phosphate exceeded the state's target concentration of 0.02 mg/L in 13 of 17 samples analyzed, yet remained under the state's long-term average of 0.152 mg/L on all occasions.

Nitrate plus nitrite as nitrogen concentrations were very similar in 1994-1995 and 2000-2001. Nitrate plus nitrite as nitrogen concentrations ranged from 0.003 mg/L to 0.381 mg/L in 1994-1995 and from nondetectable to 0.381 mg/L in 2000-2001. The state's target concentration of 0.25 mg/L of nitrate plus nitrite as nitrogen was only exceeded on the January 30, 2001 and February 9, 1995 sampling dates at the deepest area site.

Table 1. Bowman-Haley Reservoir Near Dam - Volume-Weighted Mean Water Chemistry Concentrations for Selected Parameters Reported During the 1994-1995 and 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2000

Parameter	1994-1995 Volume-Weighted Mean	2000-2001 Volume-Weighted Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1406 mg/L	2344 mg/L	1545 mg/L
Hardness as Calcium	253 mg/L	456 mg/L	474 mg/L
Sulfates as SO_4	754 mg/L	1378 mg/L	785 mg/L
Chlorides	11.6 mg/L	14 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	317 mg/L	374 mg/L	229 mg/L
Bicarbonate	359 mg/L	399 mg/L	274 mg/L
Conductivity	2022 umhos/cm	3169 umhos/cm	1984 umhos/cm
Total phosphorus as PO_4	0.049 mg/L	0.057 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.154 mg/L	0.135 mg/L	0.117 mg/L
Total Ammonia as N	0.096 mg/L	0.226 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	1.299 mg/L	1.448 mg/L	1.775 mg/L

Table 2. Bowman-Haley Reservoir South Arm - Volume-Weighted Mean Water Chemistry Concentrations for Selected Parameters Reported During the 1994-1995 and 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2000

Parameter	1994-1995 Volume-Weighted Mean	2000-2001 Volume-Weighted Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1372 mg/L	2344 mg/L	1545 mg/L
Hardness as Calcium	243 mg/L	456 mg/L	474 mg/L
Sulfates as SO_4	743 mg/L	1378 mg/L	785 mg/L
Chlorides	11.6 mg/L	14 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	308 mg/L	374 mg/L	229 mg/L
Bicarbonate	359 mg/L	399 mg/L	274 mg/L
Conductivity	2078 umhos/cm	3169 umhos/cm	1984 umhos/cm
Total phosphorus as PO_4	0.029 mg/L	0.057 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.003 mg/L	0.135 mg/L	0.117 mg/L
Total Ammonia as N	0.047 mg/L	0.226 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	1.176 mg/L	1.448 mg/L	1.775 mg/L

Table 3. Bowman-Haley Reservoir North Arm - Volume-Weighted Mean Water Chemistry Concentrations for Selected Parameters Reported During the 1994-1995 and 2000-2001 LWQA Projects and the Arithmetic Mean for all North Dakota Lakes Sampled Between 1995 and 2000

Parameter	1994-1995 Volume-Weighted Mean	2000-2001 Volume-Weighted Mean	1995-2001 North Dakota Mean
Total Dissolved Solids	1328 mg/L	2388 mg/L	1545 mg/L
Hardness as Calcium	228 mg/L	461 mg/L	474 mg/L
Sulfates as SO_4	724 mg/L	1405 mg/L	785 mg/L
Chlorides	10.9 mg/L	14 mg/L	64 mg/L
Total Alkalinity as $CaCO_3$	307 mg/L	378 mg/L	229 mg/L
Bicarbonate	310 mg/L	398 mg/L	274 mg/L
Conductivity	2069 umhos/cm	3180 umhos/cm	1984 umhos/cm
Total phosphorus as PO_4	0.029 mg/L	0.056 mg/L	0.152 mg/L
Nitrate + Nitrite as N	0.009 mg/L	0.123 mg/L	0.117 mg/L
Total Ammonia as N	0.066 mg/L	0.189 mg/L	0.272 mg/L
Total Kjeldahl Nitrogen	0.907 mg/L	1.365 mg/L	1.775 mg/L

LIMITING NUTRIENT

Data collected in 1994-1995 and 2000-2001 indicate that Bowman-Haley Reservoir is phosphorus limited. In brief, the primary nutrients driving Bowman-Haley Reservoir's trophic response are nitrogen and phosphorus. For identifying which of these nutrients is limiting, the ratios of total nitrogen to total phosphorus (N:P) are examined. For purposes of this report, when the N:P ratio is 15, the nutrients nitrogen and phosphorus are assumed to be in balance. A ration greater than 15 indicates a phosphorus limitation, and a ratio less than 15 indicates a nitrogen limitation.

Ratios of N:P during both 1994-1995 and 2000-2001 indicate that Bowman-Haley Reservoir is phosphorus limited (Figure 2). In 1994-1995, the ratios of total nitrogen to total phosphorus ranged between 27.5 and 36. In 2000-2001, the ratios ranged between 19 and 34.6 indicating that Bowman-Haley Reservoir is phosphorus limited.

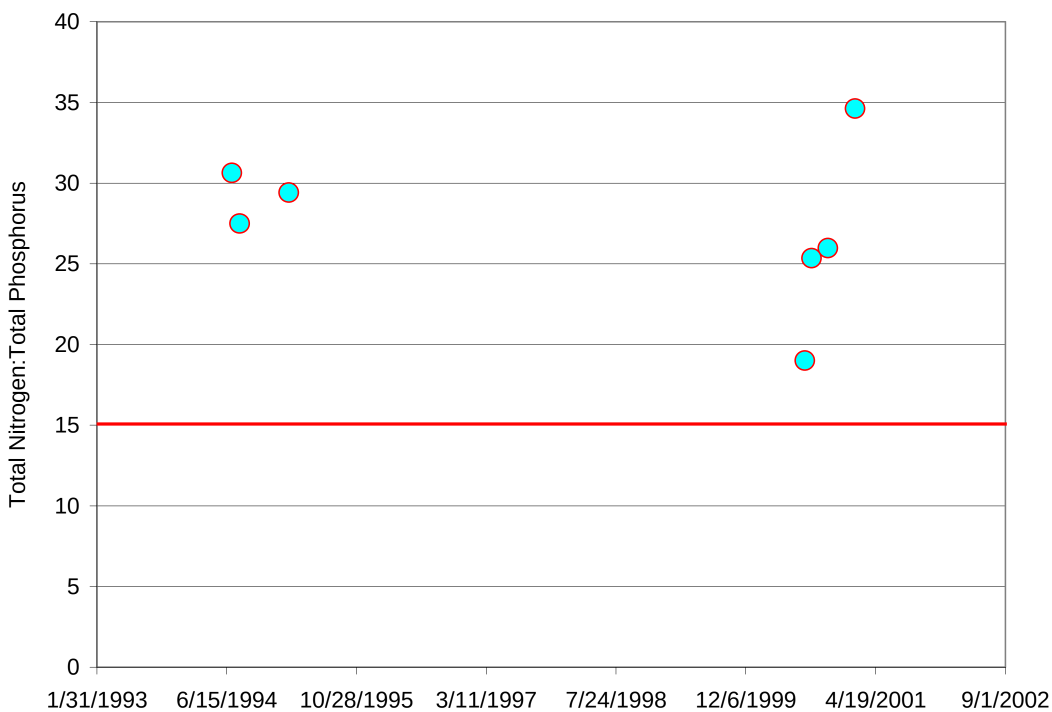

Figure 2. Bowman-Haley Reservoir Total Nitrogen to Total Phosphorus Ratio

TEMPERATURE AND OXYGEN

Temperature and oxygen profiles collected in 2000-2001 (Figures 3, 5 and 7) indicate Bowman-Haley Reservoir is usually not thermally stratified. This is supported by the 1994-1995 data as well (Figures 9, 11 and 13). Of the seven temperature profiles collected in 1994-1995 and the four profiles collected in 1999-2000, only in July of 1994 was Bowman-Haley Reservoir thermally stratified.

Oxygen profiles collected in 2000-2001 indicated that Bowman-Haley is well oxygenated throughout the entire year and at all depths (Figures 4, 6, 8). This was supported by data collected in 1994-1995 as well (Figures 10, 12 and 14).

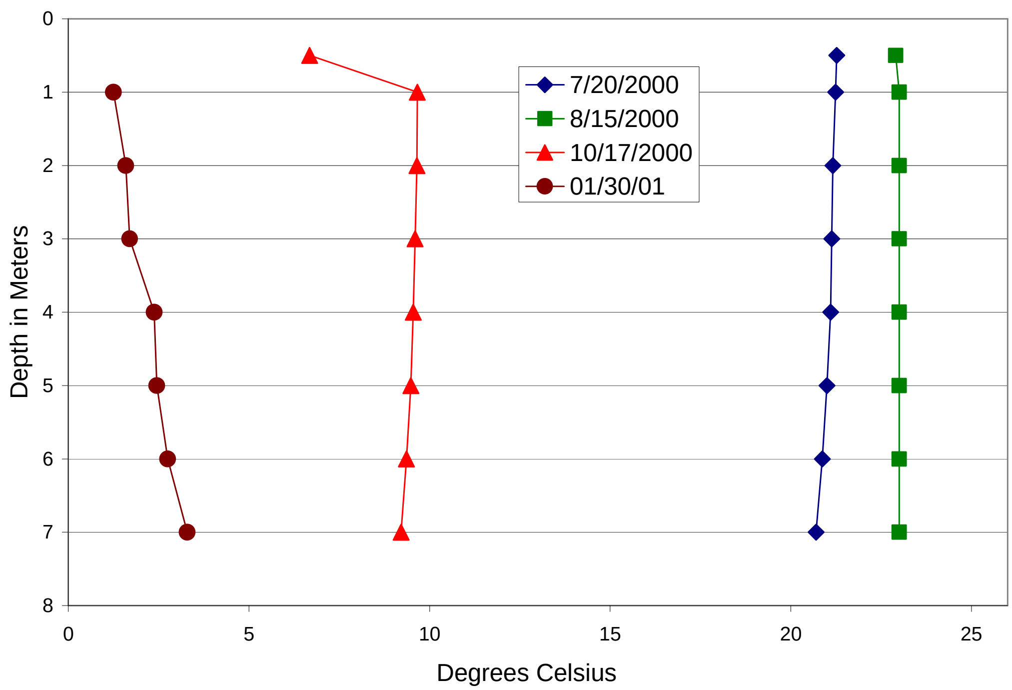

Figure 3. Bowman-Haley Reservoir Near Dam - 2000-2001 Temperature Profiles

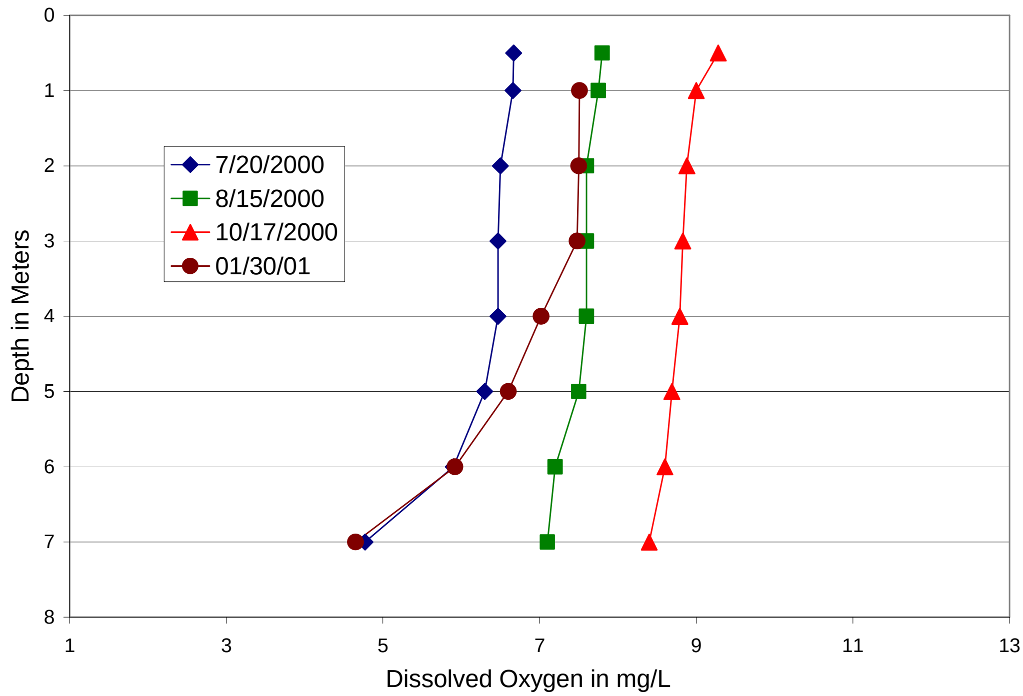

Figure 4. Bowman-Haley Reservoir Near Dam - 2000-2001 Dissolved Oxygen Profiles

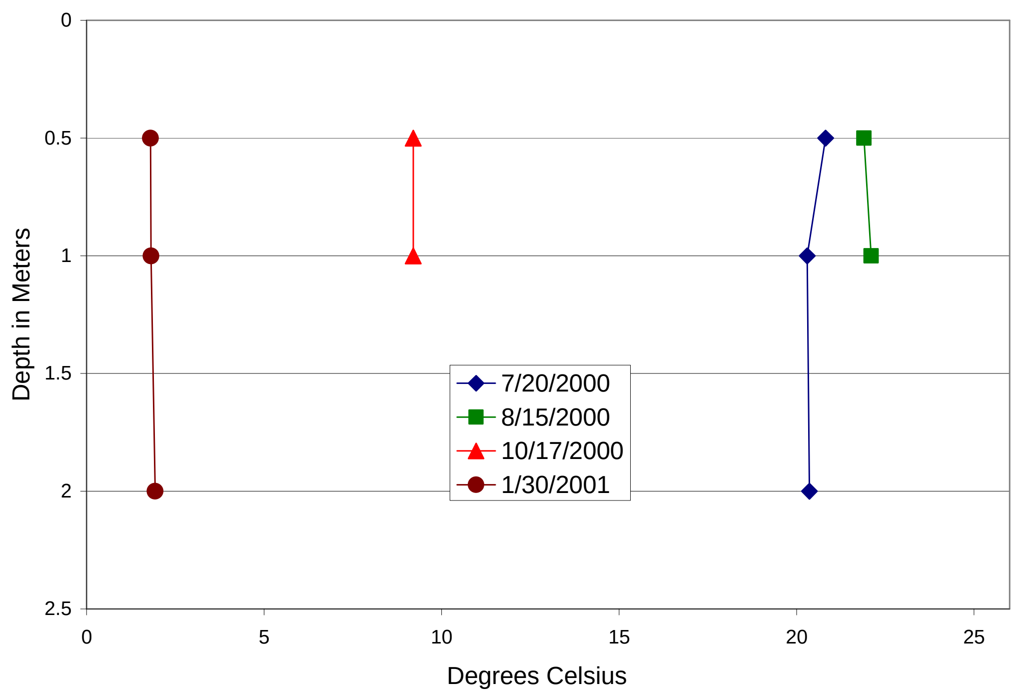

Figure 5. Bowman-Haley Reservoir South Arm - 2000-2001 Temperature Profiles

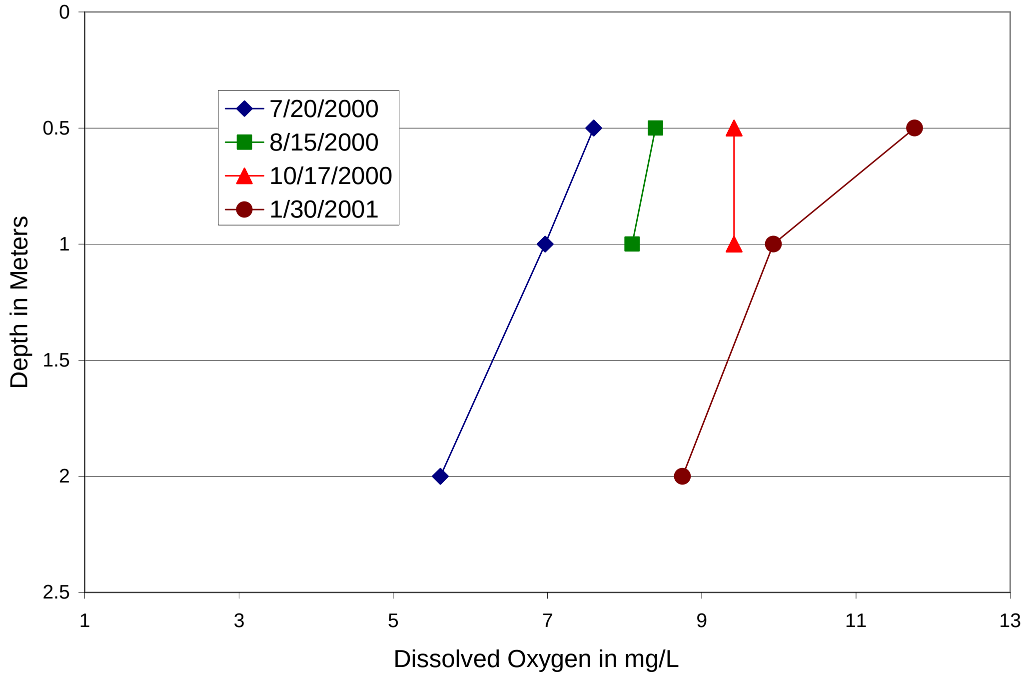

Figure 6. Bowman-Haley Reservoir South Arm - 2000-2001 Dissolved Oxygen Profiles

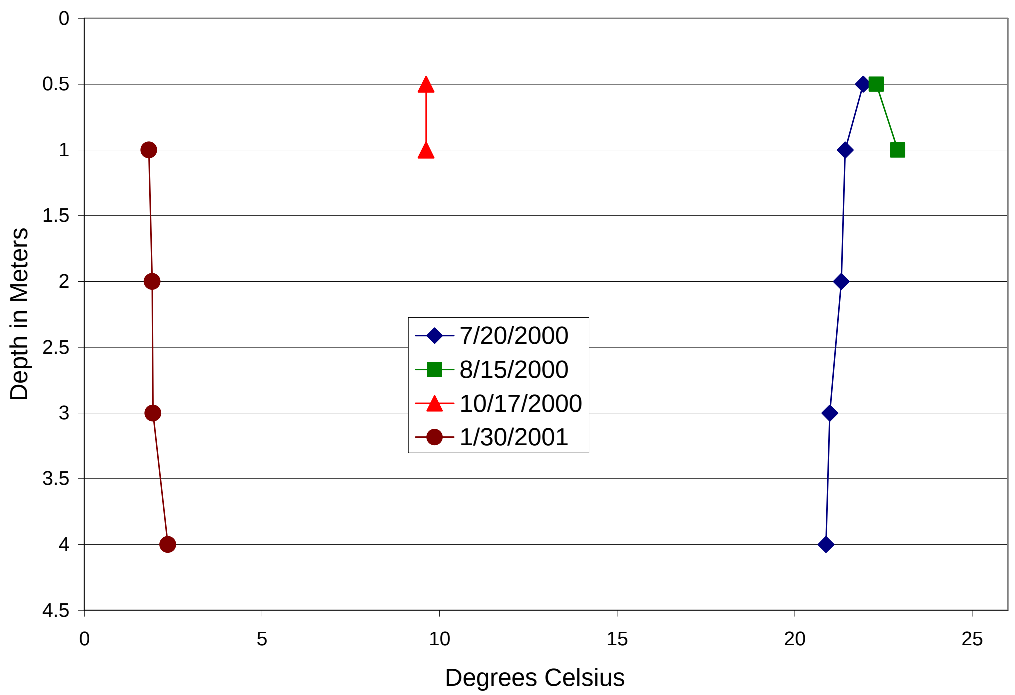

Figure 7. Bowman-Haley Reservoir North Arm - 2000-2001 Temperature Profiles

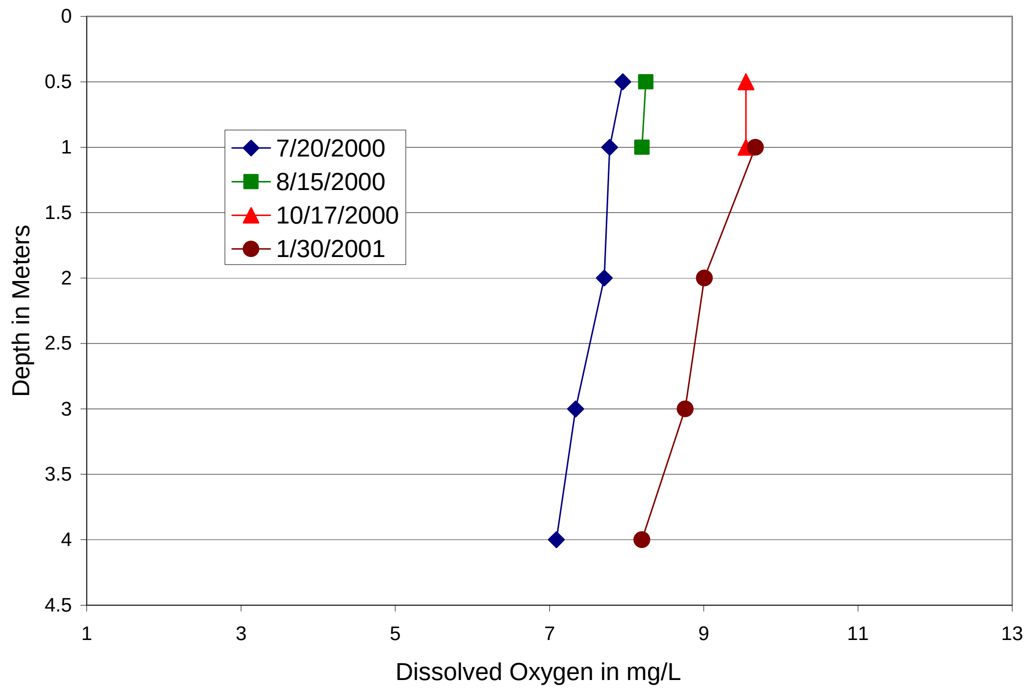

Figure 8. Bowman-Haley Reservoir North Arm - 2000-2001 Dissolved Oxygen Profiles

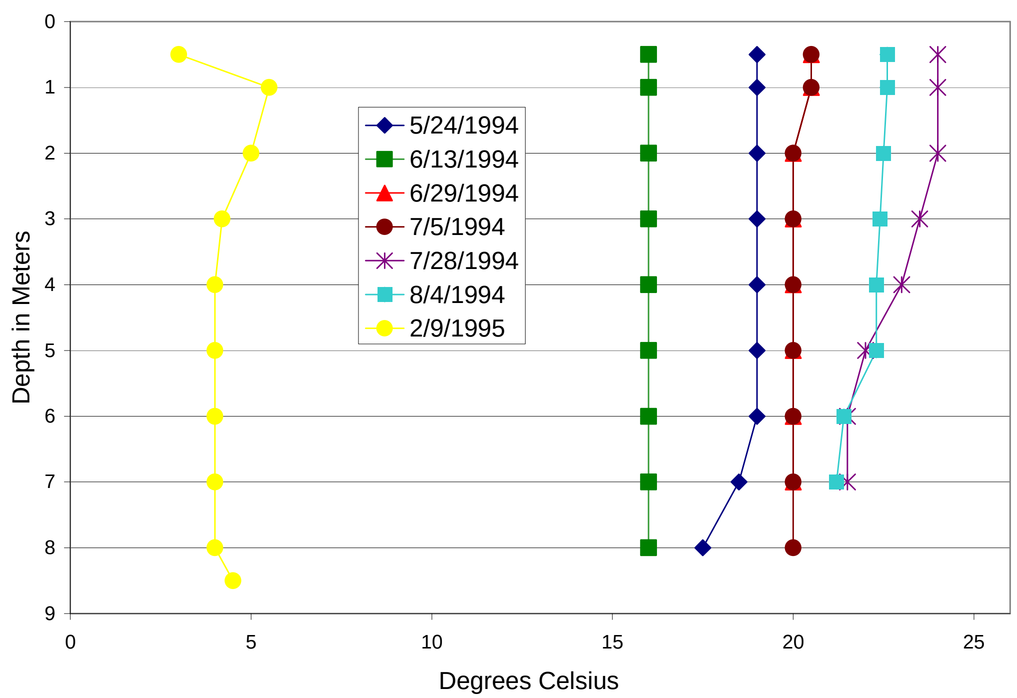

Figure 9. Bowman-Haley Reservoir Near Dam - 1994-1995 Temperature Profiles

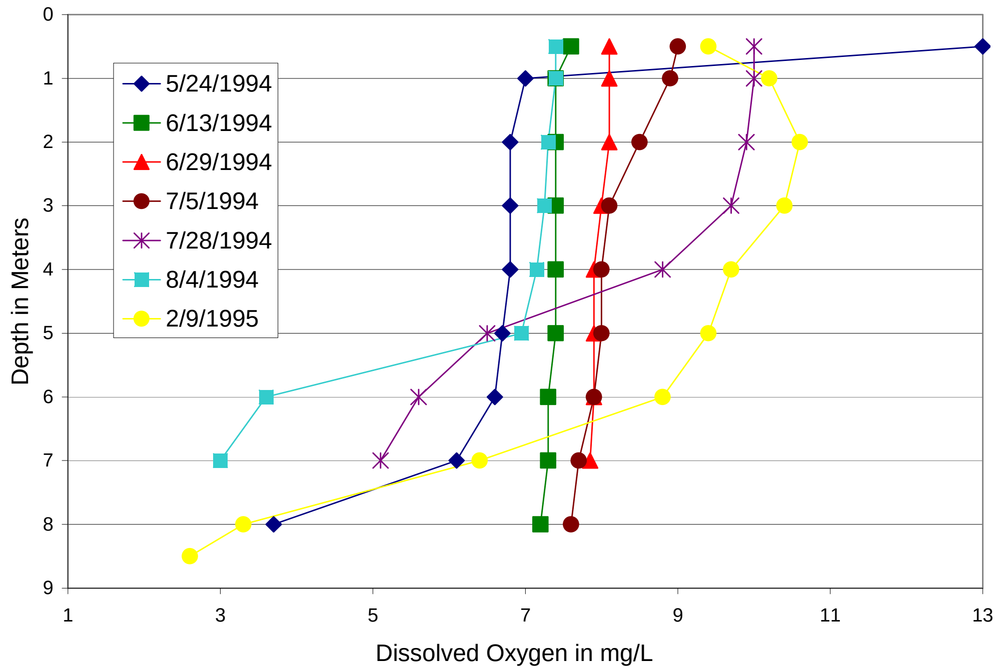

Figure 10. Bowman-Haley Reservoir Near Dam - 1994-1995 Dissolved Oxygen Profiles

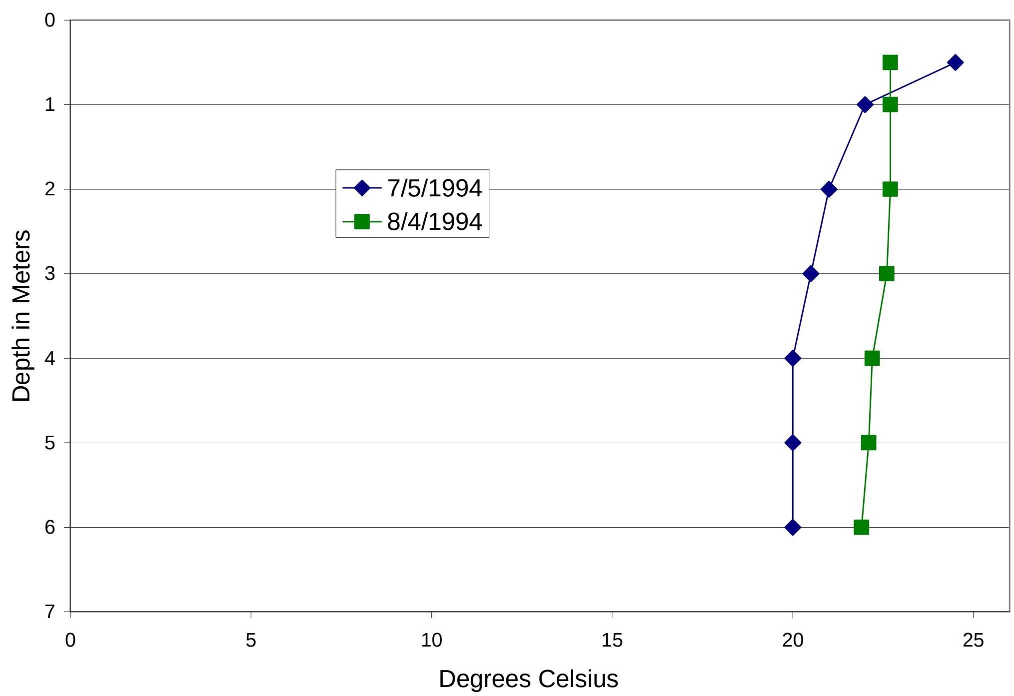

Figure 11. Bowman-Haley Reservoir South Arm - 1994-1995 Temperature Profiles

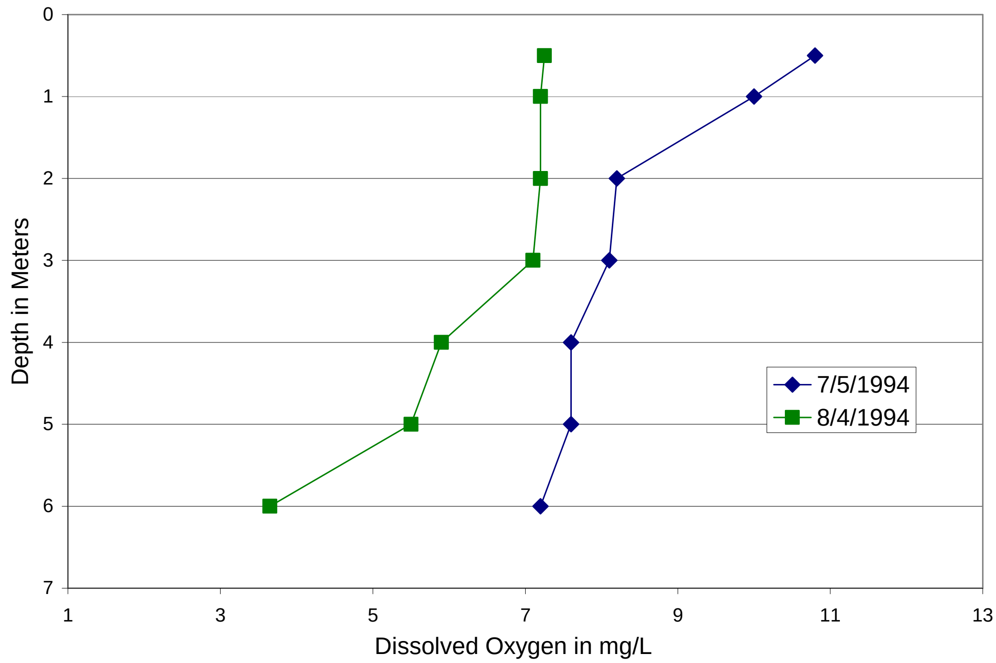

Figure 12. Bowman-Haley Reservoir South Arm - 1994-1995 Dissolved Oxygen Profiles

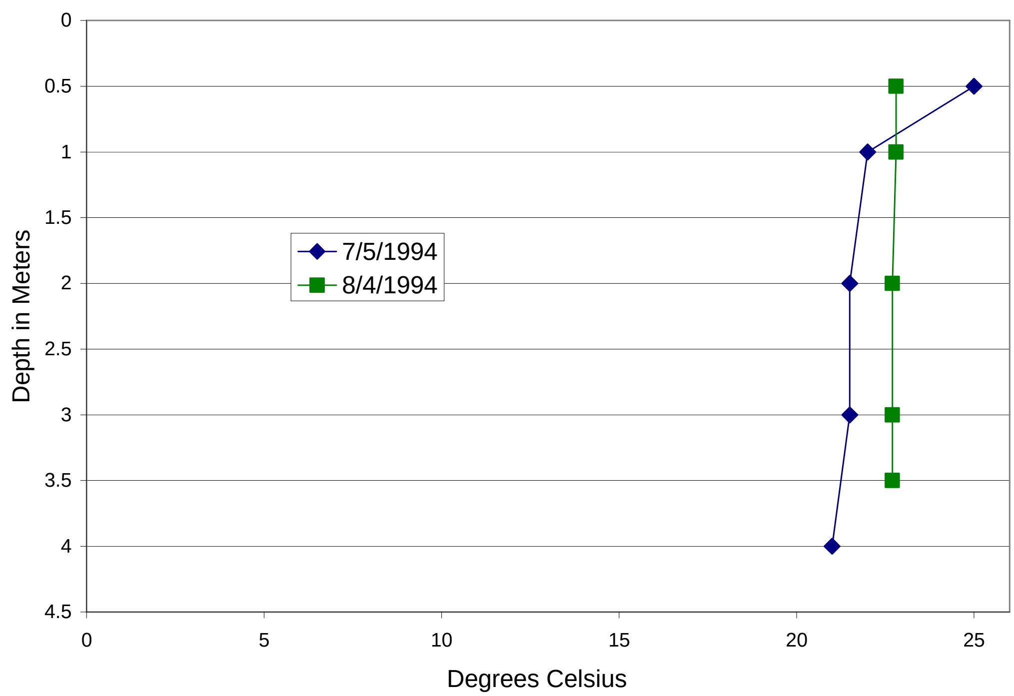

Figure 13. Bowman-Haley Reservoir North Arm - 1994-1995 Temperature Profiles

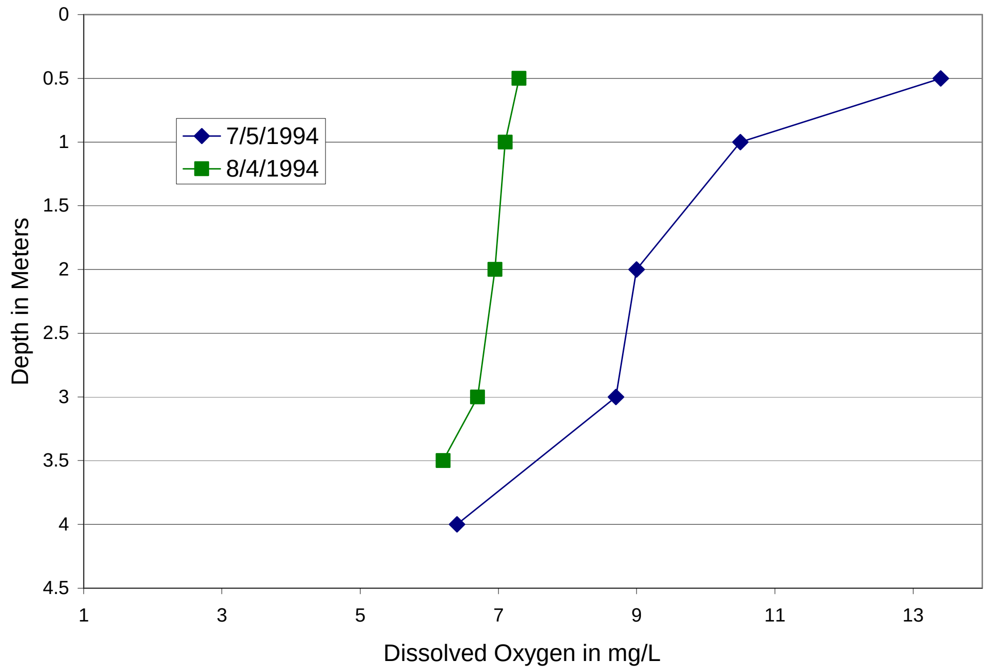

Figure 14. Bowman-Haley Reservoir North Arm - 1994-1995 Dissolved Oxygen Profiles

TROPHIC STATUS

For purposes of this project, Bowman-Haley Reservoir is classified as eutrophic. This project estimated trophic status using Carlson’s Trophic Status Index (TSI) (Carlson 1977). Carlson’s TSI was selected because of its common use among limnologists and because it was developed for lakes in Minnesota, a state geographically close to North Dakota. Carlson’s TSI uses a mathematical relationship based on secchi disk transparency, concentrations of total phosphorus at the surface and chlorophyll-a concentrations. This numerical value then corresponds to a trophic condition ranging from 0 to 100 with increasing values indicating a more eutrophic condition (Figure 15).

Trophic status estimates were calculated for the three sample sites on Bowman-Haley Reservoir indicating that the reservoir is eutrophic. Trophic status was estimated by averaging Carlson's Trophic Status Index (TSI) scores for secchi disk transparencies, total phosphorus and chlorophyll-a, and this estimate included only data collected during the open-water period in 2000. Scores for each zone sampled were 51, 61 and 59 for an average of 57 near the dam, 53, 54 and 64 for an average of 57 in the south arm, and 45, 58 and 71 for an average of 58 in the north arm. Carlson's TSI scale places all the averages in the middle of the eutrophic range.

While far from conclusive, a comparison of the 2000 TSI estimates to1994 estimates suggests that the trophic condition of Bowman-Haley Reservoir is improving. Carlson TSI scores in 1995-1995 were between 50 and 61 for an average of 55.5 near the dam, between 65 and 63 for an average of 64 in the south arm and between 59 and 60 for an average of 60.5 in the north arm. Ancillary data supporting an improved lake condition is a reduction in nutrient fluctuation and a slower dissolved oxygen deduction rate with increasing depths.

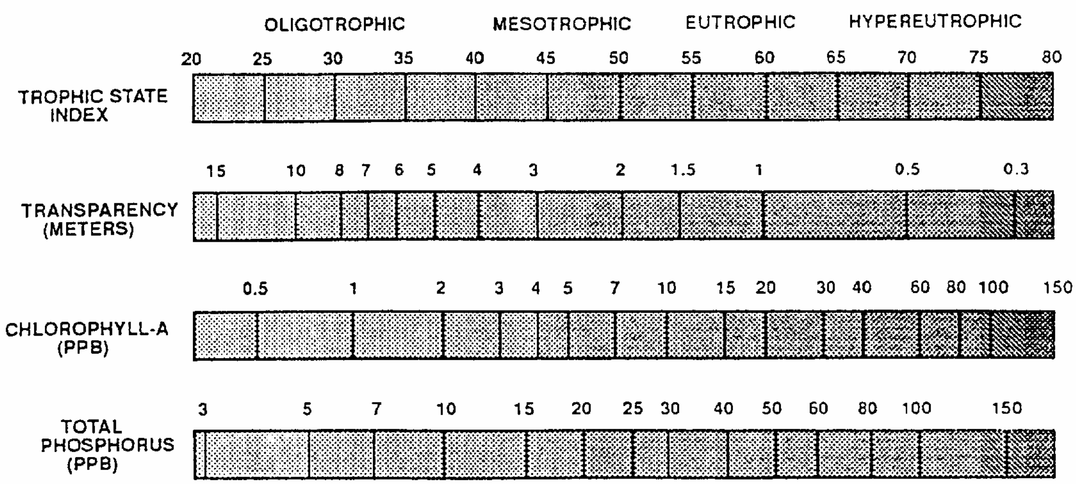

Figure 15. Graphic Depiction of Carlson's Trophic Status Index

SEDIMENTS

Sediment samples were collected from Bowman-Haley Reservoir at all three water quality monitoring sites. Sediments were collected using a 1-inch core sampler, and samples were composed of at least the top 6 inches of sediments. Sediment samples were analyzed for 12 elements and 14 pesticides (Table 4).

Sediment samples collected from Bowman-Haley Reservoir contained detectable levels of all trace elements tested with the exception of mercury. Reported concentrations of trace elements in the sediment samples collected from Bowman-Haley Reservoir were compared to sediment samples collected from similar locations throughout the state of North Dakota between 1991 and 1995. The database contained samples from 86 lakes and reservoirs.

Table 4. List of Analytes Completed for Sediment Samples Collected from Bowman-Haley Reservoir in 1994

Analyte	Analyte	Analyte
Aluminum (Al)	Manganese (Mn)	Iron (Fe)
Copper (Cu)	Zinc (Zn)	Barium (Ba)
Chromium (Cr)	Lead (Pb)	Mercury (Hg)
Hoelon	2-4-D	Dicamba
Dinoseb	MCPA	Tordon
2-4-5-T	Silvex	Pentachlorobenzoic Acid
Bromoxynil	Dichloprop	Bentazon

In general, the reported concentrations of trace elements in the sediments collected from the deepest and inlet areas were low. Nearly all of the reported concentrations from these areas were below the 25th percentile. The only exceptions were the reported chromium and arsenic concentrations in the sediments collected from the Spring Creek and Alkali Creek inlets which were equal to or slightly exceeded the 75th percentile.

However, the littoral area sediments had reported concentrations of trace elements that were nearly all above the 75th percentile. In particular are the reported concentrations of barium, chromium and arsenic that either equaled or exceeded the 90th percentile.

Concentrations of PCBs and selected organic compounds were all below detectable levels in sediments collected from Bowman-Haley Reservoir.

WHOLE FISH ANALYSIS

Fish were collected for contaminant analysis from Bowman-Haley Reservoir on May 24, 1994. Species of fish collected included walleye, bluegill, white sucker and redhorse sucker (representing piscivore, insectivore and bottom feeders). The walleye sample was composed of three fish with a mean weight of 483 grams and a mean length of 37.2 centimeters. The bluegill sample was composed of five fish with a mean weight of 210 grams and mean length of 19.9 centimeters. The white sucker sample was composed of five fish with a mean weight of 1004 grams and a mean length of 44 centimeters. The redhorse sucker sample was composed of four fish with a mean weight of 1030 grams and a mean length of 43.9 centimeters.

Evaluation of the fish tissue data was accomplished by comparing each sample to the statistical percentiles for all fish samples from similar groups (i.e., piscivores, insectivores and bottom feeder) collected throughout the entire state between 1991 and 1994.

Trace element concentrations reported in the walleye sample generally were low. The exceptions were the reported concentrations of chromium, selenium and lead which either equaled or exceeded the 75th percentile.

Detectable pesticide residues in the composite walleye sample were DDE, DDD and Triallate. DDE and DDD are both breakdown derivatives of the agricultural insecticide DDT. Both DDE and DDD can behave similarly to the parent compound when available to the environment. Triallate, commonly known as Far-Go, is a selective pre-emergent herbicide used throughout North Dakota. Of the concentrations reported, only the Triallate concentration was higher than the state's 50th percentile. The reported concentration of 0.009 micrograms per liter (µg/L) was only exceeded by three of 84 piscivore samples collected and analyzed between 1991 and 1994.

Trace element concentrations reported in the bluegill sample were also low. Almost all of the reported concentrations were below the 50th percentile. The exceptions were barium, chromium, lead and mercury which exceeded the 50th percentile but were below the 75th percentile.

The detectable pesticides found in the bluegill sample were the same three reported in the walleye sample (DDE, DDD and Triallate). Another similarity to the walleye sample was the relatively high Triallate concentrations. The concentration of 0.005 µg/L reported in the bluegill sample was the highest concentration reported for a panfish at that time.

The two bottom feeder samples collected were very similar to each other in the amounts of trace elements and organic compounds detected. Both samples had reported concentrations of trace elements that generally were low, not only compared to other bottom feeders but compared to all fish samples in general. The only exceptions were the reported concentrations of chromium and lead that exceed the 75th percentile.

Contaminants detected in the white sucker and redhorse sucker samples included BHC Alpha, DDE, DDD, PCBs, Triallate and Trifluralin. BHC Alpha-like DDE and DDD are breakdown derivatives of a pesticide banned in the early 1970s. Triallate (Far-Go) and Trifluralin (Treflan) are selective pre-emergent herbicides that are widely used in North Dakota. PCBs are generally considered industrial wastes and are commonly used in plasticizer and dialectic fluids.

The reported concentrations of BHC Alpha and PCBs in the two sucker samples were equal to or greater than the highest concentrations reported for any bottom feeders during the four years of data collection. The white sucker contained concentrations of BHC Alpha and PCBs of 0.003 µg/L and 0.090 µg/L, respectively. The redhorse sucker contained concentrations of 0.002 µg/L and 0.050 µg/L, respectively.

The other detectable compounds in the white sucker sample were DDE and DDD. Concentrations of both DDE and DDD were below the 50th percentile for all bottom feeders sampled.

The redhorse sucker sample contained detectable concentrations of DDE, DDD, Triallate and Trifluralin. While all concentrations were low, the triallate concentration of 0.010 µg/L was the highest concentration reported for this compound in any bottom feeder sampled.

WATERSHED

Bowman-Haley Reservoir has a watershed that covers approximately 475 square miles primarily in Bowman County, North Dakota and Harding County, South Dakota. The watershed is composed of gently rolling to rolling, arid to semiarid country studded with the occasional prominent butte. The major land use is livestock production followed by small grain and row crops. The land is dry yet fertile, easily tilled and highly susceptible to water and wind erosion. Average annual precipitation in this region is 14 inches. Rainfall is often swift and severe with 20 percent of the annual rainfall commonly arriving in 24- to 48-hour bursts.

The land has been sculptured into its current form by the ever-present wind. The prominent buttes are a testimony to the tenacity of the sandstone cap rocks to resist the wind. They stand like giants overseeing the landscape and serve as permanent land marks for travelers. This is the only region of North Dakota that has either never been glaciated or was glaciated so long ago that there are no recognizable remains.

Between two-thirds and three-quarters of the Bowman-Haley watershed is in a use associated with livestock production (Table 5). The remaining one-quarter to one-third is in small grain or row crop production, CRP, roads, farmsteads, wildlife management, lakes and miscellaneous uses such as cemeteries and churches.

Table 5. Land Use in the Bowman-Haley Reservoir Watershed (percentages based on a 1994 survey performed by the National Resources Conservation Service)

Landuse	Landuse Percentages
Cropland	31
Rangeland	12
Hayland	6.7
CRP	9.3
Wet/Wild[1]	39
Feedlots[2]	1
Farmsteads[3]	1

[1]Wet/Wild are wildlife management areas, wetlands and lakes.
[2]Feedlots are areas where livestock are concentrated to be fed.
[3]Number present in watershed.

Nonpoint source pollution accounts for 100 percent of the nutrient and sediment loading to Bowman-Haley Reservoir. The U.S. EPA defines nonpoint source pollution as "pollution caused by diffused sources that are not regulated as point sources and is normally associated with agricultural, silvicultural and urban runoff, runoff from construction activities, etc. Such pollution results in the man-made or human-induced alteration of the chemical, physical, biological and radiological integrity of the water. In practical terms, nonpoint source pollution does not result from a discharge at a single location, (such as a single pipe) but generally results from land runoff, precipitation, atmospheric deposition or percolation. Pollution from nonpoint sources occurs when the rate at which pollutant materials entering waterbodies or groundwater exceeds natural levels."

In 1990, the Bowman-Slope SCD implemented the Bowman-Haley Watershed Project. The project's goal was to reduce agricultural nonpoint source pollution of the tributaries to Bowman-Haley Dam. The project began in the spring of 1990 and continued through June 1999. Over the course of the project, the annual median concentrations of total phosphorus, total nitrogen and total suspended solids were reduced by 87, 66 and 84 percent, respectively, by reducing nonpoint source pollution on more than 63 percent of the watershed (Table 6).

Table 6. Annual Median Water Quality Concentrations in mg/L, Acres Treated and Percentage of Watershed Treated. (Treatment percentages include all programs combined and are included in the table as implemented two years after the contract dates for CRP and one year after the contract date of all other best management practices.)

Year	Total Phosphorus	Total Nitrogen	Total Suspended Solids	Acres Treated	% of Watershed Treated
1989[1]	Not Sampled	Not Sampled	Not Sampled	530.1	1.5%
1990	Not Sampled	Not Sampled	Not Sampled	1,179.1	3.2%
1991	Not Sampled	Not Sampled	Not Sampled	4,390.5	12.0%
1992	Not Sampled	Not Sampled	Not Sampled	7,056.2	19.4%
1993	0.562	2.62	57	13,475.2	36.9%
1994	0.315	2.33	24	14,608.2	40.0%
1995	0.134	1.09	10	17,027.1	46.7%
1996	0.105	1.17	17	17,027.1	46.7%
1997	0.144	1.06	13	18,871.2	51.2%
1998	0.059	0.98	11	23,137.2	63.4%
1999	0.070	0.90	9	23,137.2	63.4%

[1]CRP contracts prior to project implementation.
[2]Water quality concentrations in mg/L.

The project goal was achieved through education and cost-share incentives to agricultural producers within the watershed. Cost share was provided to minimize the financial hardship incurred when upgrading from traditional rangeland, tillage and livestock practices to sustainable practices that reduced soil erosion and nutrient transport.

Water quality monitoring was initiated to document the success or failure of the project. Water quality monitoring began in the spring of 1990 and continued through June of 1999. A single long-term monitoring station was developed on Alkali Creek.

Alkali Creek is a 36,480-acre sub-watershed (Figure 16) of the Bowman-Haley Reservoir's 300,000- to 340,000-acre watershed. Water quality parameters monitored included total suspended solids, total phosphorus, total nitrogen, total inorganic nitrogen and nitrate + nitrite as nitrogen. Water quality data was collected in a regimen that mimicked the natural hydraulic curve of the region on a schedule that targeted 20 annual samples. Timing for the project could not have been better.

In 1989, the project steering committee was successful in applying for a Hydraulic Unit Area (HUA) project designation for the Bowman-Haley Watershed. The HUA designation provided producers in the watershed with cost-share assistance through the Soil Conservation Service's Great Plains Conservation Plans (GPCP) and the Agricultural Stabilization Service's Long Term Agreements (LTA). It also provided two Soil Conservation Service staff to implement the project.

At the start of the project in 1990, the agricultural community had five options for financial assistance: four through traditional United States Department of Agriculture (USDA) programs and one from the Environmental Protection Agency's Section 319 program. Later in the project, a sixth source, the USDA's Water Quality Incentive Program (WQIP) was utilized. Since there was no way to differentiate between the effects of one conservation program from another, all reported effects are cumulative.

A drought during the first two years of the project prevented the collection of good baseline water quality data. Even so, a clear trend toward lower concentrations of total phosphorus, total nitrogen and total suspended solids was evident (Figures 17, 18 and 19).

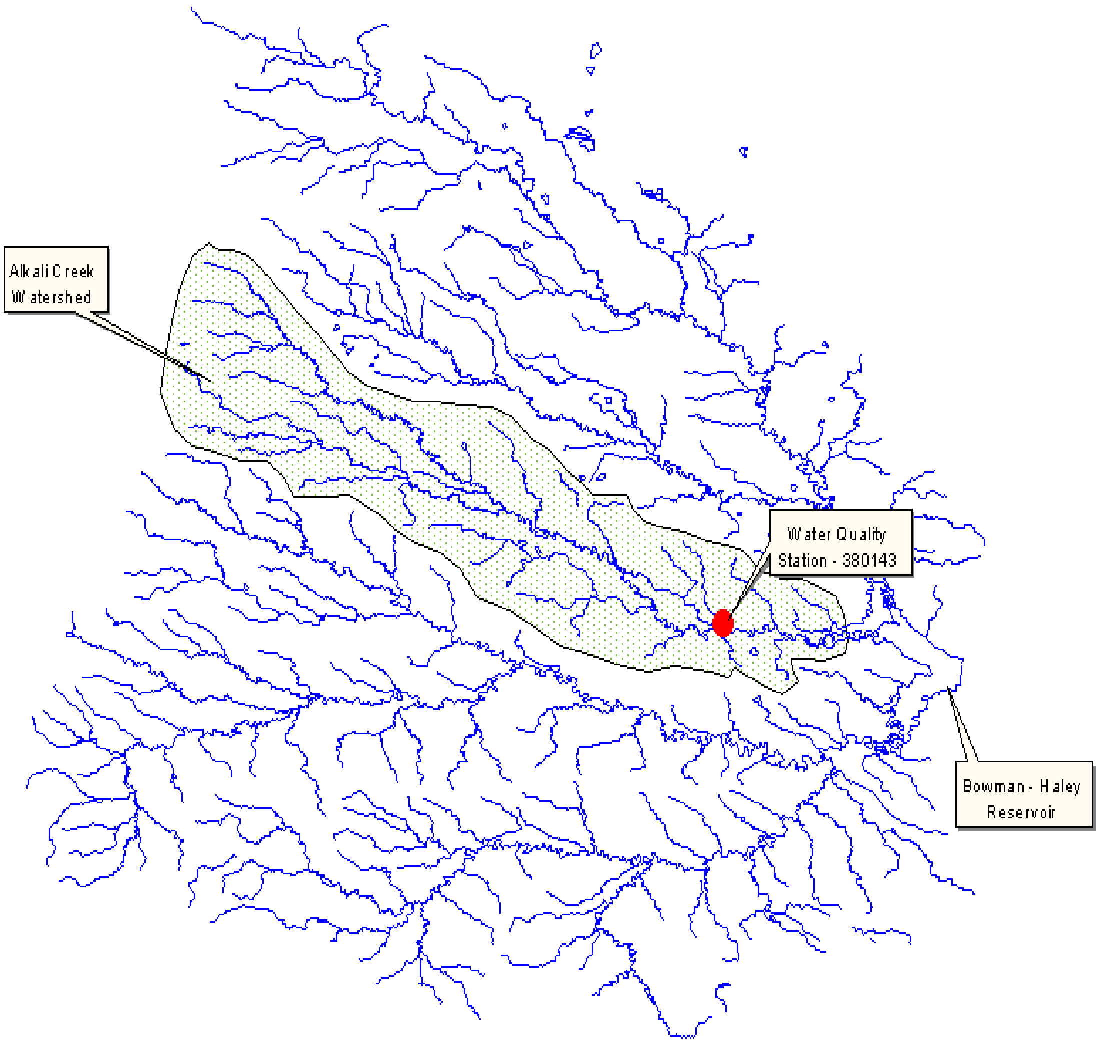

Figure 16. Location of Long-Term Water Quality Monitoring Station on Alkali Creek in Bowman-Haley Watershed

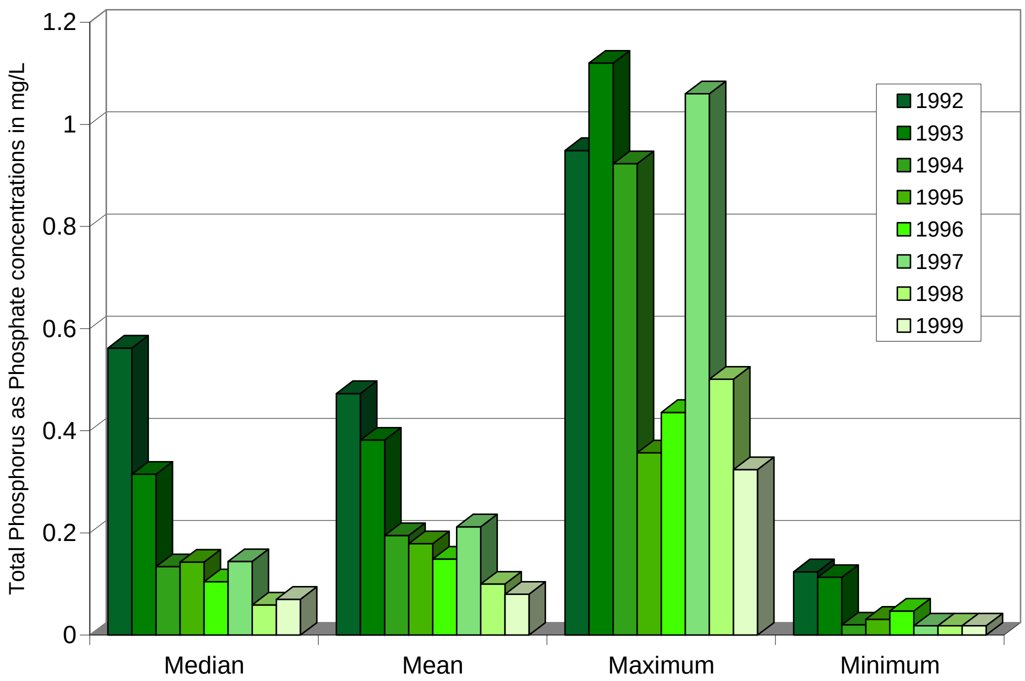

Figure 17. Descriptive Statistics for Total Phosphorus at the Long-Term Monitoring Station on Alkali Creek

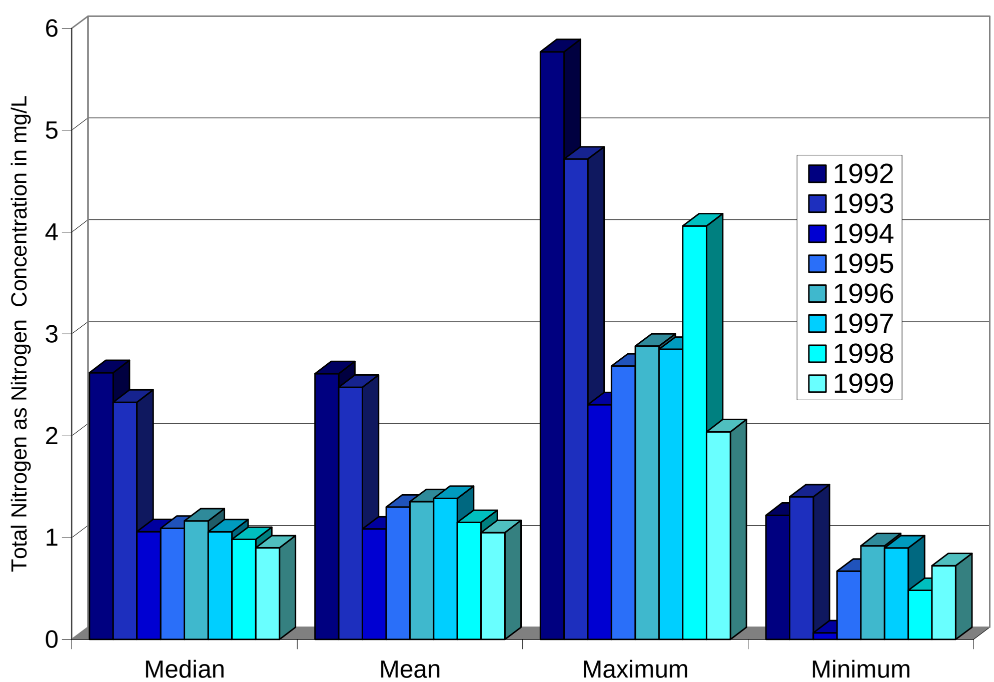

Figure 18. Descriptive Statistics for Total Nitrogen at the Long-Term Monitoring Station on Alkali Creek

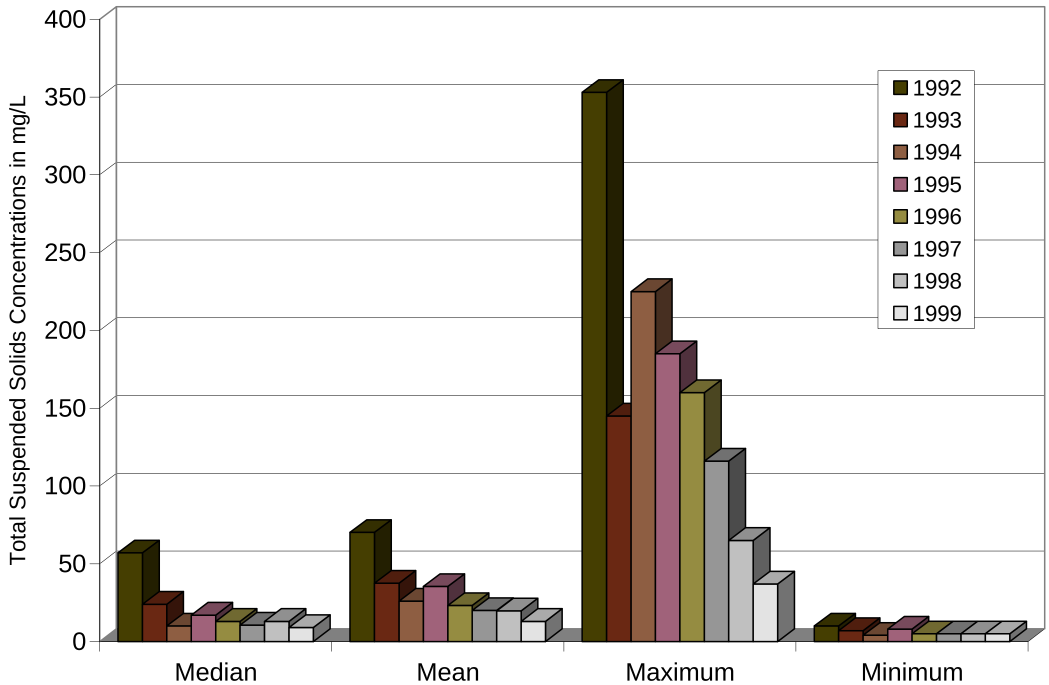

Figure 19. Descriptive Statistics for Total Suspended Solids at the Long-Term Monitoring Station on Alkali Creek

The water quality data also showed that the relationship between the responses in water quality to improvements in land use was not linear. The near-baseline condition resisted change until approximately 35 percent of the watershed was treated (Figures 20, 21 and 22); however, once the threshold for change was reached, water quality improvements were rapid and sustained.

In conclusion, the water quality data shows that the Bowman-Haley Watershed Project was effective at reducing pollutant concentrations in Alkali Creek. Pollutants affected included both nutrients and suspended solids. Just as importantly, the project's water quality data emphasizes the level of commitment needed (i.e., percentage of land area treated) to achieve a measurable change in water quality.

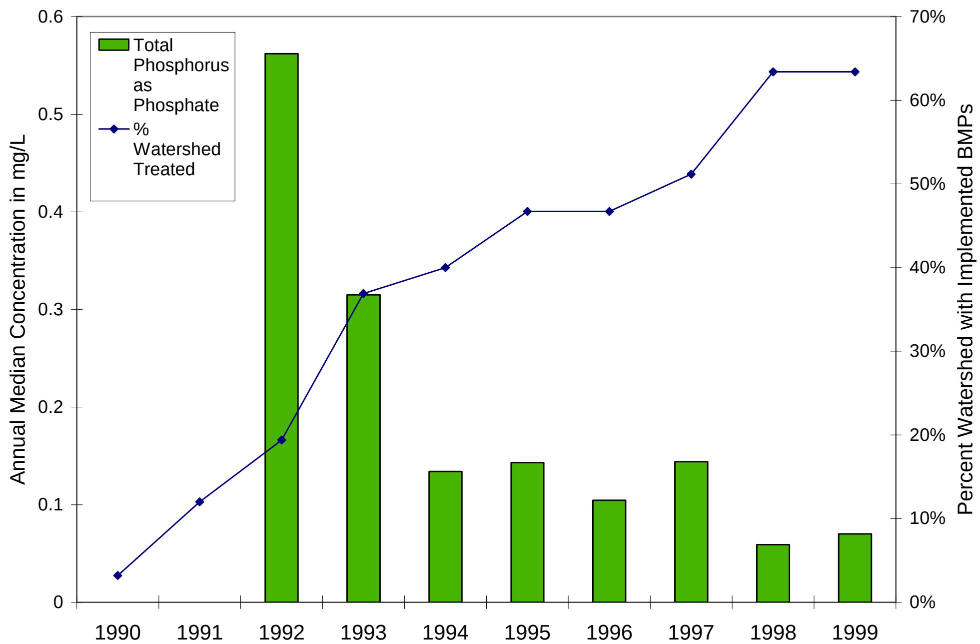

Figure 20. Relationship between Percentage of Watershed with BMP Implementation and Reductions in Median Concentrations of Total Phosphorus

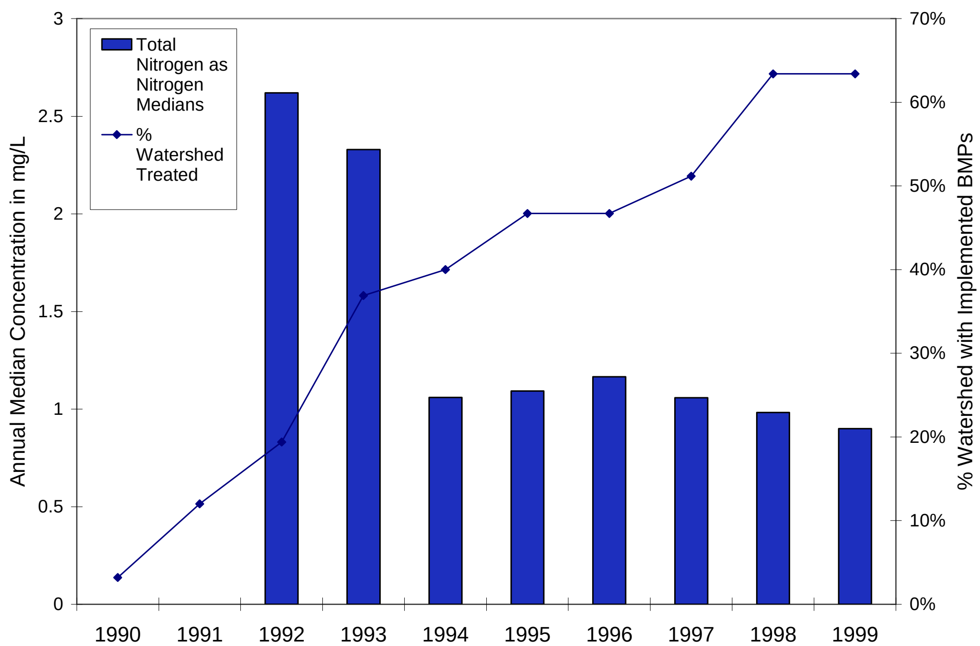

Figure 21. Relationship between Percentage of Watershed with BMP Implementation and Reductions in Median Concentrations of Total Nitrogen

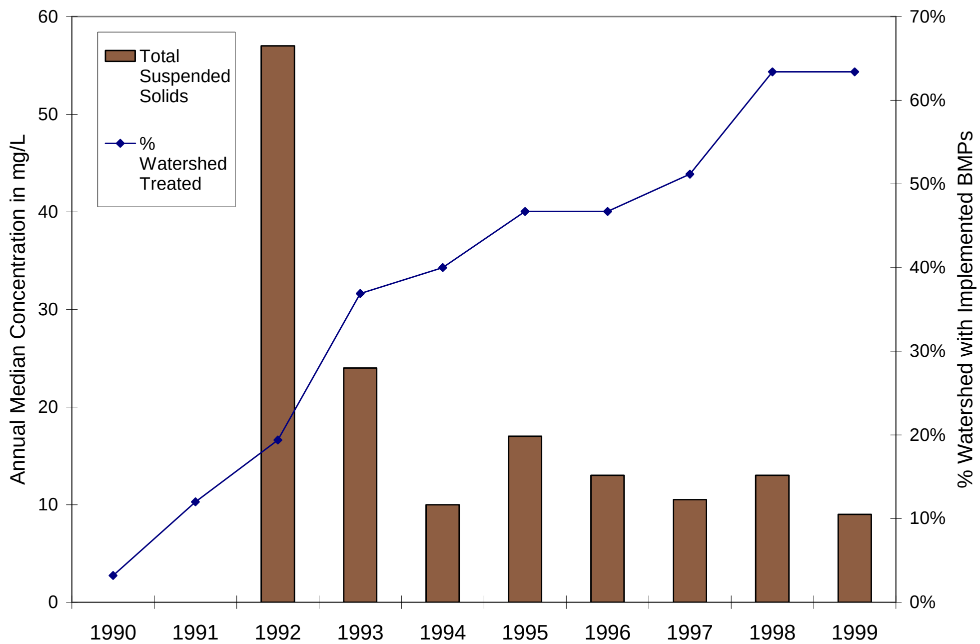

Figure 22. Relationship between Percentage of Watershed with BMP Implementation and Reductions in Median Concentrations of Total Suspended Solids